The change of surface wind in the north Western Siberia since 1966

M V Reshetko, A V Chernikova and E V Vasina

Tomsk Polytechnic University, 30 Lenin Avenue, Tomsk, 634050, Russia
E-mail: mrechetko@tpu.ru

Abstract. The statistical analysis of near-surface wind characteristics has been performed in the territory of the North of Western Siberia. The conclusion on wind speed decrease of different intensity for different directions and increase of calmness frequency is made. The maximum changes in wind speed are observed in winter and summer seasons, in transitional seasons these values are lower. The most intensive changes in wind direction frequency occur in summer; the less intensive ones are typical for winter.

1. Introduction

Modern climate changes in different parts of the globe are connected with changes of atmospheric processes durability that lead to changes in meteorological characteristics. Taking into account the climate changes it is necessary to highlight the relevance of assessing modern and expected climate-related changes in water balance, and, hence, water resources and cycle. One of the major meteorological variables for different research spheres is a speed and direction of near-surface wind. As a result of changes in atmospheric circulation, the air mass behavior coming to the territory of the Lower Ob River also changes. Therefore, it defines the peculiarities of hydrologic behavior of water bodies and environmental flow. Based on these facts the results of statistical analysis of near-surface wind are considered in the territory of the North of Western Siberia. The goal of the research is to reveal the trends in changes of near-surface wind speed and direction.

2. Materials and methods

2.1. Subject of research

The study area is characterized by long winters (7–8 months), mean monthly temperatures of which are -23–29 °C, whereas minimal ones reach -60 °C. Harsh climate is complicated by strong winds [1, 2]. In summer cyclones intensify. Summers are cold due to frequent north winds and cloudy weather. The mean temperature in July changes from 10 to 14 °C, the maximal temperature sometimes reaches 30 °C. During summer season light frosts and snow are possible. On average, summer lasts about 40–60 days. The mean annual air temperature in the territory is -5–7 °C, in some regions it is -10°C. The research area is characterized by excessive moisture and is considered the most hyperhumid area of Russia [1, 2].

To study the wind behavior the following weather stations were chosen: Berezovoye (63.93 N 65.05 E) and Tolka (63.98 N 82.08 E) located on approximately the same latitude and Marresal (69.72 N 66.80 E) and Salekhard (66.50 N 66.68 E) located on approximately the same longitude. The altitude of these weather stations is within the range of 15-31 meters above the sea level.

Marresal weather station is located on the coast of the Kara Sea, where winds are stronger with wind mean speed being 8-9 m/s in winter and 5-6 m/s in summer. At Salekhard station mean wind speed is 3.5-7 m/s [1, 2]. At Marresal weather station winds of south quarter prevail in winter, north and north-west wind directions – in summer, the number of calmnesses is 4% in winter, and 17% in summer. At Salekhard weather station south winds prevail in winter period, but north-east ones are in summer, the amount of calm winds in winter is 16%, but in summer 8%. At Marresal weather station mean annual wind speed is higher in winter period, but at Salekhard the maximums are observed in summer period.

At Tolka weather station the maximum wind speed is observed in April, May (3m/s), the minimum one – in January, February (2.2 m/s). At Berezovoye weather station the maximum wind speed is observed in May, June (4.3 m/s), whereas the minimum one is in February, January (3.3 m/s). The prevailing wind direction at Tolka weather station is south-east quarter in winter season, and those of north-west and north directions in summer. At Berezovoye station the prevailing wind direction is winds of south-west quarter in winter season, but those of north-east and north directions in summer season. At both weather stations the wind speed is higher in transition seasons than in warm and cold seasons. At all weather stations, except Marresal station located on the coast, calm wind conditions are more often in winter than in summer [1, 2].

2.2. Materials and methods

The research materials were taken from special database of current observations (every 3 hours) of wind direction and speed at the stations Berezovoye, Tolka, Salekhard within the period from 1966 till 2014 and Marresal weather station within the period from 1977 till 2014 [1]. At each station the wind direction frequency from 8 points of compass was calculated for each month and mean wind speed for each month and a year in every direction over the research period.

Afterwards, the statistical analysis of the data on time series of surface wind was performed. For long-term data record the test of statistical inhomogeneity was conducted. The research methods included verification of null hypothesis of observation series homogeneity using Student's, Abbe's [3] and Fisher's tests; randomness and presence of trend was tested by means of Pitman's and reversal criteria [4]. The conclusion on series homogeneity or assignable change was made at the significance level 0.05 when estimated module values exceeded the corresponding critical or extended the allowed limits.

3. Results and discussion

Based on the research the statistical inhomogeneity of more than half of data series has been established. For Tolka 77% of mean annual wind speed series are inhomogeneous, but for Berezovoye all series are inhomogeneous. Besides, for Tolka weather station 63% of direction frequency series and mean wind speed in regard to every direction are inhomogeneous, but for Berezovoye they are 53% and 73%, respectively. Within the research period Berezovoye weather station is known to be relocated 1.5 km to the south-west in 1983 that can be a cause for climatic data inhomogeneity. For Marresal weather station 67% of mean annual wind speed series and 25% of direction frequencies are inhomogeneous; for Salekhard station 92% and 67% are respectively inhomogeneous.

The statistically significant negative trend of mean monthly and annual wind speed is established (table 1), which corresponds to the previous research, for instance [5]. One of the reasons for changes of near-surface wind characteristics is change in large-scale atmospheric circulation, namely, increase in durability of anticyclonic weather over Western Siberia [6].

It should be noted that the most changes in wind speed are observed in winter and summer periods. In transition seasons the values of trends are lower. In addition, positive trends of wind speed are recorded, for example, at Marresal weather station which is located on the coast. Besides, absence of statistically significant changes in wind speed at Tolka station in the second half of winter is to be taken into account.

Table 1. The values of statistically significant changes of mean wind speed (m/s over 10 years).

	v, m/s over 10years			
month	Berezovoye	Tolka	Marresal	Salekhard
I	-0.40	-	-0.14	-0.37
II	-0.29	-	-0.05	-0.33
III	-0.25	-	-0.02	-0.27
IV	-0,21	-0.08	**+0.06**	-0.31
V	-0.23	-0.15	-0.26	-0.43
VI	-0.33	-0.25	-0.15	-0.44
VII	-0.31	-0.13	-0.14	-0.34
VIII	-0.31	-0.15	-0.05	-0.25
IX	-0.3	-0.08	-0.13	-0.26
X	-0.35	-0.13	-0.01	-0.27
XI	-0.4	-0.17	**+0.12**	-0.31
XII	-0.38	-0.13	**+0.08**	-0.30
year	-0.31	-0.13	-0.06	-0.31

The research has revealed the trends in long-term series of mean speed and frequency of wind directions from 8 points of compass every month. The increase in frequency was mainly established for north-east, south-east, south-west, and north-west winds. For Berezovoye and Marresal stations the increase in calmness frequency in all months was proved, but for Tolka station – in June. As for Berezovoye and Salekhard stations the negative trend in mean speed was statistically proved in all months (table 1) and for a number of annual values. On the whole, during a year at Salekhard station the increase in frequency of south-west, south-east, and north-west winds was revealed (figure 1). At Marresal station positive trends in frequency of north and south winds as well as calm conditions were stated; the frequency in south-west and south-east wind decreased.

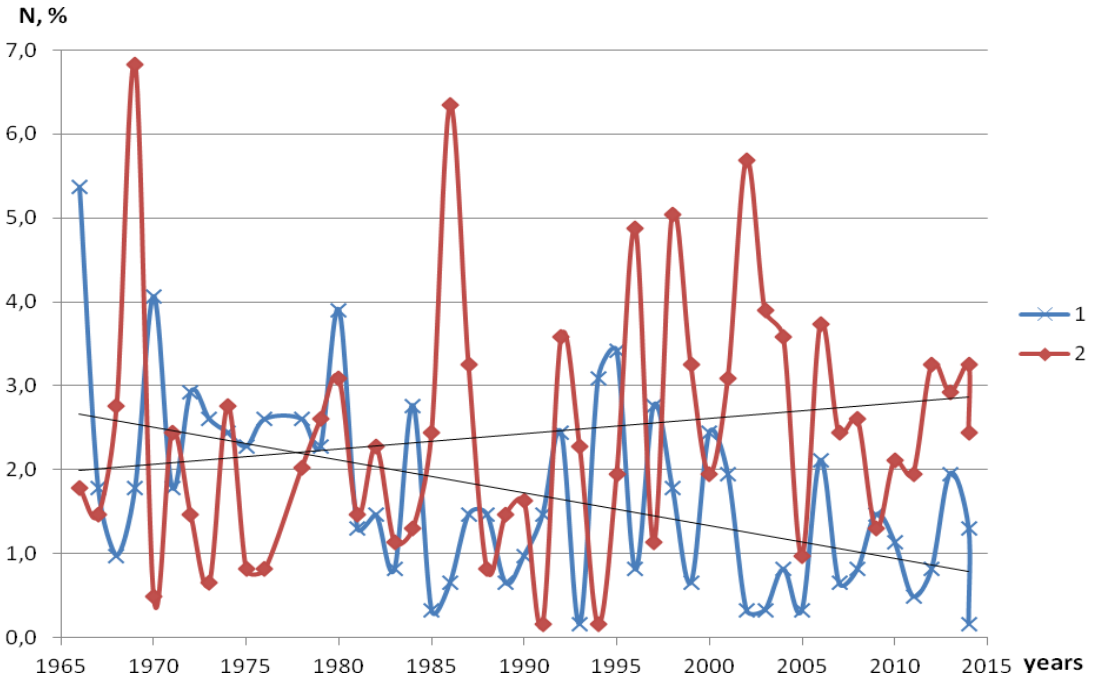

Figure 1. Long-term changes in frequency (N) of east (1) and north-west (2) wind of Salekhard weather station in March with linear trend, 1966-2014

As a result of research in near-surface circulation the changes in wind direction frequency and speed have been considered in each direction for the seasons of typical annual circulation.

Considering Tolka weather station the authors distinguished 4 types of seasons typical for near-surface circulation – winter (November, December, January, February), summer (June, July, August) and transition seasons – spring (April and May) and autumn seasons (September, October). Similar to autumn season the wind rose is observed in March. In winter the frequency of south-west and north-east directions increases and wind speed decreases 0.1 m/s on average in south (figure 2), south-west and south-east directions (south quarter), as well as east direction.

As for Berezovoye station the following types of seasons typical for near-surface circulation are to be distinguished – winter (from October till February), summer (May - July) and transitional seasons – autumn (August, September) and spring in March. Similar to autumn season the wind rose is observed in April. In October wind rose is close to autumn season, but it has its peculiarities. In summer the frequency of south-east and south-west directions increases. At the same time, the frequency of north-west and west directions does not change. The frequency of calmness increases. The decrease in wind speed occurs mostly in south-west and south directions as well as in north-east and east within the range from 0.25 to 0.35 m/s on average.

For Salekhard station – winter (November, December, January, February), summer (May, June, July, August) and transitional seasons: autumn (September, October) and spring (but March and April are different). In winters the frequency of south-east, south-west and north-west directions increases, but the speed of south-west quarter and north and north-east directions decreases 0.3 m/s on average. In summer the frequency of south-east, south-west and north-west directions increases, wind speed decreasing in all direction except the winds of south quarter (S-W, S, S-E).

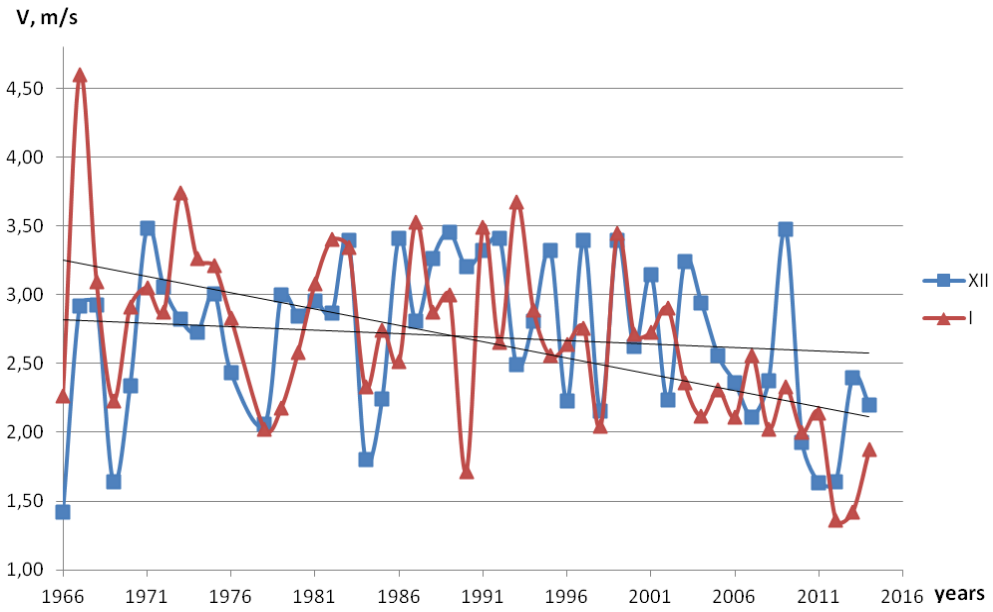

Figure 2. Long-term changes in mean wind speed of south direction at Tolka weather station in January (I) and December (XII), 1966-2014

At Marresal weather station 5 types of seasons typical for near-surface circulation are distinguished – winter (from November till February), summer (May - August) and transitional seasons – the first one occurs with north direction increase (March - May) and separately (October) and (September). In winter the frequency of north, east winds increases, whereas that of south-west, north-west and west decreases. The frequency of calmness increases in all months, not only in winter. In this case there is a

slowdown of wind speed in south-west direction in January and east one in December. There is also a 0.1 m/s increase of wind speed in north direction on average. In summer a decrease of north-east, east and south-east direction as well as south and south-west is observed, but there is an increase of north one. The frequency of calmness grows as well. The speed mostly decreases for winds of west direction.

The most intensive changes in wind direction frequency take place in summer period, the less intensive ones are observed in the first half of winter period. Most often the mean monthly near-surface speed of south quarter wind decreases (S-E, S, S-W). Less often the changes occur for the winds of north quarter (N-W, N, N-E).

4. Conclusions

In the course of research it is stated that the mean annual and monthly wind speed slows down and calmness frequency increases. The maximal changes in wind speed are observed in winter and summer periods, whereas in transitional seasons the values are lower. Over the year most often monthly near-surface wind speed of south quarter directions decreases. Less often similar changes occur for the north quarter winds.

The most intensive changes in frequency of wind directions are registered in summer period, less intensive ones are typical for the first half of winter period. It should be noted that there is an increase in frequency of wind direction not typical for the given season. Besides, decrease in speed of winds typical for the given season is observed nearly at all weather stations. The growth of wind frequency in the north quarter in winter and in the south quarter in summer may result in more temperature variability, changes in heat and moisture advection. Thus, the analysis of long-term transformations in near-surface wind characteristics allows the conclusion on slowing down of wind speed, different in intensity in directions of different points of compass and increasing calmness frequency at weather stations in the north of Western Siberia.

References

[1] FGBU VNIIGMI MCD [Electronic resource] access: http://meteo.ru/data (in Russian)
[2] National Atlas of Russia, Ecology and Nature vol 2 [Electronic resource] URL: http://национальныйатлас.рф/ (in Russian)
[3] Rapp J Ch D 1996 Schönwiese Atlas der Niederschlags- und Temperaturtrends in Deutschland 1891-1990 *Frankfurter Geowissenschaftliche Arbeiten Serie B Meteorologie und Geophysik* (Frankfurt a. M.) **5** 255
[4] Bendat J and Piersol A 1989 *Applied analysis of random data* (Moscow: Mir) p 540 (in Russian)
[5] McVicar T R, Roderick M I, Ling Tao Li 2012 *J. of Hydrology*. Global review and synthesis of trends in observed terrestrial near-surface wind speeds: Implications for evaporation. Vol. **416-417** pp. 182–205.
[6] Gorbatenko V P, Ippolitov I I and Podnebesnykh N V 2007 *Russian Meteorology and Hydrology*. Atmospheric Circulation Over Western Siberia in 1976-2004 32. Vol. **5** pp. 301-306